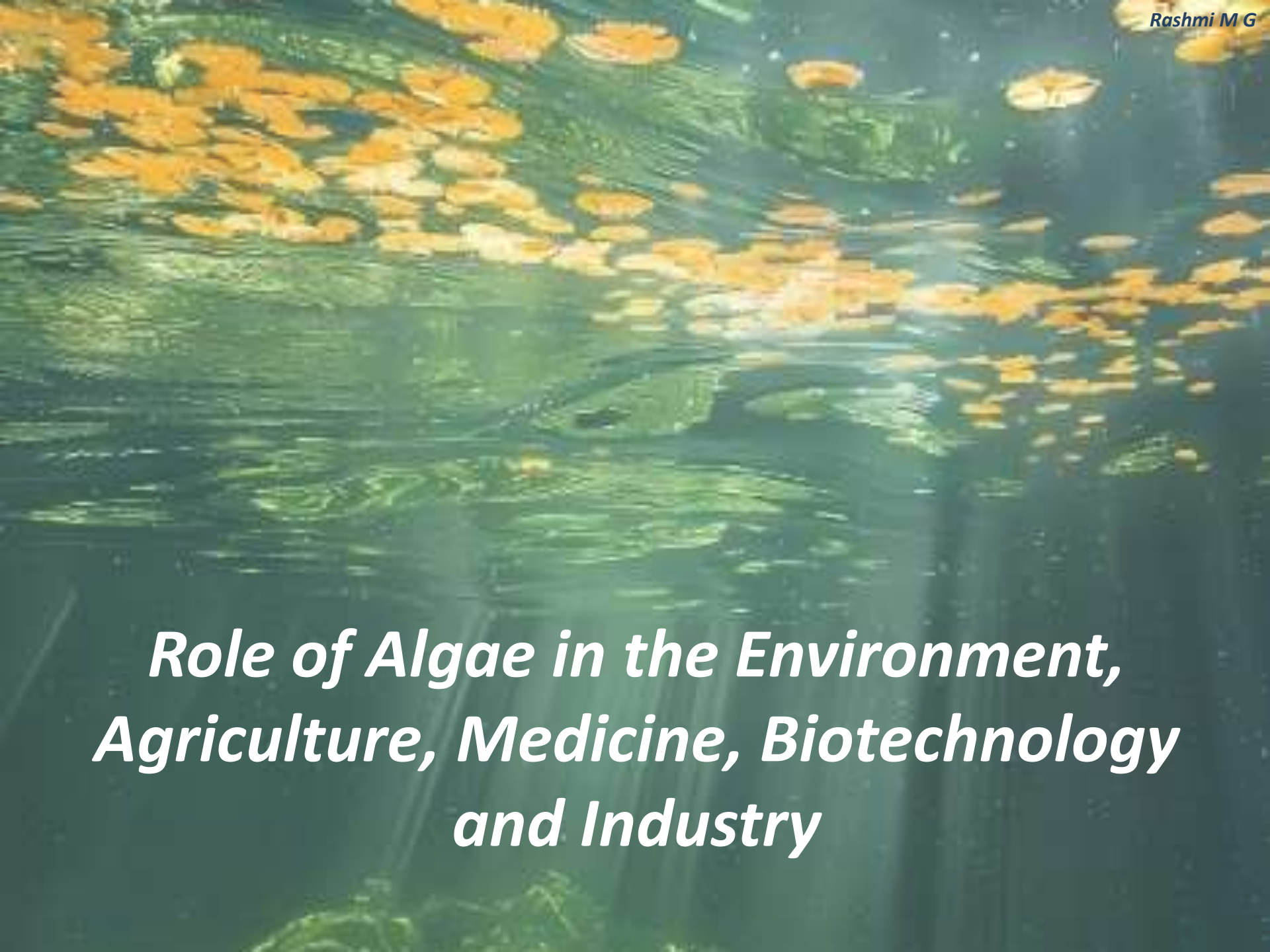
Rashmi M G



Role of Algae in the Environment, Agriculture, Medicine, Biotechnology and Industry

Let's summarize what Algae are,

- Algae are given many names like, 'Pond Scum', 'Frog spittle', 'Water Mosses', Sea weeds'
- These are group of eukaryotic organisms, that have chlorophyll a and carry out oxygen-producing photosynthesis
- The study of Algae is Phycology (The word Phycology is derived from the Greek word *Phykos*, meaning seaweed
- The term algae (Singular- Alga) was originally used to define simple "Aquatic plants"
- These group of eukaryotes differ from other photosynthetic eukaryotes in lacking a well-organized vascular conducting system and in having very simple reproductive structures
- In sexual reproduction the whole organism may serve as a gamete; unicellular structures (gametangia) may produce gametes; or gametes can be formed by multicellular gametangia in which every cell is fertile

- **Distribution of algae:**
- Occur commonly in water (fresh, marine or brackish)
- They may occur suspended (planktonic) or attached and living on the bottom (benthic)
- They also occur in water-atmosphere interface (neustonic)
- Phytoplanktons- made up of algae and small plants
- Zooplanktons- consists of animals with algae attached to it and nonphotosynthetic protists
- Some grow on moist rocks, wood, trees and on the surface of moist soil
- Algae also live as endosymbionts in various protozoa, mollusks, worms and corals
- Several algae grow as endosymbionts within plants, some are attached to the surface of various structures and few lead a parasitic existence
- Algae associate with fungi to form lichens

Freshwater alga
Spirogyra

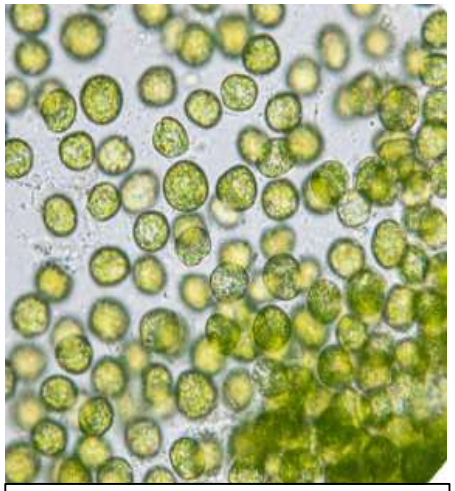
Marine alga
Macrocystis

Rock and trunk alga
Scytonema

Snow alga
Chlamydomonas nivalis

Soil alga
Nostoc

Endosymbiont with protozoa
Paramecium bursaria



Endosymbiont with plant
Chlorella

Algae with fungi
Trentepohlia

Microalgae and macroalgae have been utilized by man for hundreds of years as food, fodder, remedies and fertilizers

Ancient records show that people collected macroalgae for food as long as 500BC in China and 1000 years later in Europe

Microalgae such as ***Arthrospira*** have a history of human consumption in Mexico and Africa

In 14th century the Aztecs harvested ***Arthrospira*** from Lake Texcoco and used to make a sort of dry cake called tecuitlatl

The use of this cyanobacteria as food in Chad dates bakes to the same period, or even earlier, to the Kanem Empire (9th century AD)

Algae as Food

- ***Nostoc*** species- regionally being used as food and herbal ingredients
- Ge-Xian-Mi has been regarded as ***Nostoc sphaeroides***
- Dried ***Nostoc*** species balls are sold in Asian markets, they are stir-fried sautéed with oysters and used in soups and as thickeners for other foods

- ***Nostoc flagelliforme***, A terrestrial cyanobacterium that naturally grows on arid and semiarid steppes in the Northern and Northwestern parts of China, where it is considered an edible delicacy with special medicinal value and great economic value
- This is also called as “Facai” (meaning hair vegetable, in another context means fortunate and get rich)

- ***Arthrospira platensis*** is a cyanobacterium (***spirulina***) used to make an unusual food called ‘dihe’ in Kanembu of Chad, It is nothing but the puree of this algae
- Dihe is mainly used to prepare ‘la souce’, a kind of vegetable broth served with corn, millet or sorghum meal which occasionally can have fish or meat as additional ingredients

Alaria esculenta is a large brown kelp found in areas of Ireland, Scotland, Iceland, Brittany (France), Norway, Canada, Russia, Japan are eaten either fresh or cooked

'Kombu' is a Japanese name for the dried macroalgae that is derived from a mixture of ***Laminaria*** species like ***L. longissima, L.japonica, L. angustata, L. coriacea*** and ***L.ochotensis*** which is seasoned and cooked that served with herring or sliced salmon

The product is 'suboshi kombu' which is derived from this alga cut into 1m length, folded and dried which is delivered to the local fisheries cooperative

In China Haidai, it is regarded as a healthy vegetable usually cooked in soups with other ingredients

Undaria is processed into variety of food products like 'suboshi wakame', 'haiboshi wakame'

The major wakame product is salted wakame which is used for various instant foods such as noodles and soups and its consumption is very popular

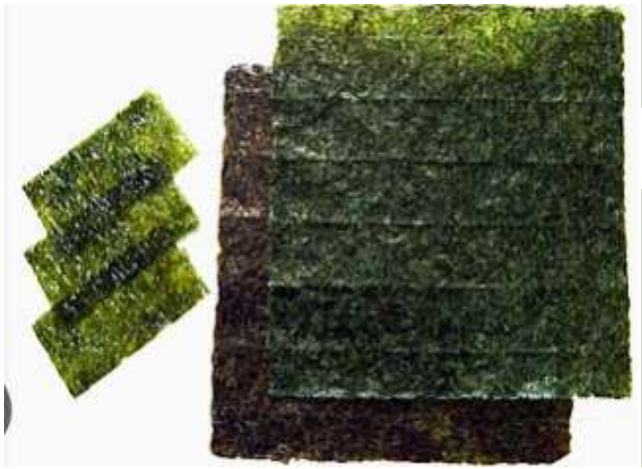
Ulva sp. Is also known as sea lettuce used as sea vegetable in in salads, sandwiches and burgers in regions of Japan, China

Caulerpa lentillifera and ***Caulerpa racemosa*** are two edible green algae used in fresh salad and known as sea grapes or green caviar

- ***Porphyra***, is popularly known as ‘Nori’ in Japan, ‘Kim’ in Korea, ‘Zicai’ in China
- It is among the most nutritious macroalgae with a protein content of 25-50% and about 75% of which is digestible

Porphyra torta, Porphyra abbottae are nutritionally and culturally important species of red alga used by First peoples of coastal British Columbia and neighboring areas, down to northern California

These species are used in large quantities, dried and processed and served in a variety of ways: toasted as a snack, cooked with clams, salmon eggs or fish in soup or sprinkled on other foods as condiments



‘Hoshi Nori’ which is dried sheets of Nori, ‘Yaki Nori’ which is toasted Nori are nutritive foods

Nori is used mainly as a luxury food. It is often wrapped around the rice ball of ‘sushi’, a typical Japanese food

- The fronds of red alga ***Palmaria*** (***Rodimenia***) ***palmata*** are known as ‘dulse’. They ae eaten raw as a vegetable substitute or dried and eaten as a condiment in North America and Europe
- Natives of Alaska consume the fronds fresh or singed on a hot stove or add the air-dried fronds to soups and fish head stews.
- It is eaten raw in Ireland, like chewing tobacco or is cooked with potatoes in soups and fish dishes

- Dulse is a good source of minerals, being very high in iron and containing all the trace elements needed in human nutrition and also has a high vitamin content

- ***Chondrus crispus***, the Irish moss/ carrageenin moss, is used as food in Ireland and some parts of Europe. It is mostly used because of its thickening powers when boiled in water, a result of its carrageenin content
- It is used in making blancmange, a traditional vanilla-flavored pudding
- It is used in macroalgae salads, 'sushimi' garnishes and as a soup ingredient

- ***Gracilaria*** also known as 'Ogo', 'Ogonori' or sea moss are used as salad vegetable
- ***Limu manauea*** and ***limu ogo*** are both sold as fresh vegetables, the latter usually mixed with raw fish
- It is also used to make jellies by boiling and making use of the extracted agar

Scientific name	*Common name and food product*	*Class*
Nostoc flagelliforme	Facai	***Cyanophyceae***
Arthrospira sp.	Dihe/ Tecuitlatl	***Cyanophyceae***
Chondrus crispus	Poica/ Irish Moss	***Floridophyceae***
Porphyra sp.	Nori/ Laber/ Zicai	***Bangiophyceae***
Palmaria palmata	Dulse	***Floridophyceae***
Callophyllis variegata	Carola	***Floridophyceae***
Asparagopsis taxiformis	Limu kohu	***Floridophyceae***
Gigartina spp.	Botelhas	***Floridophyceae***
Gracilaria sp.	Limu manauea, Ogo, Ogo nori/ Sea moss	***Floridophyceae***
Sargassum echinocarpum	Limu kala	***Pheophyceae***
Dictyopteris plagiogramma	Limu lipoa	***Pheophyceae***

Scientific name	*Common name and food product*	*Class*
Undaria sp.	Wakame	***Pheophyceae***
Laminaria spp.	Kombu	***Pheophyceae***
Nereocystis spp.	Black kelp	***Pheophyceae***
Hizikia fusiforme	Hiziki/ Hijiki	***Pheophyceae***
Alaria esculenta	Oni-wakame	***Pheophyceae***
Cladosiphon okamuranus	Mozuku	***Pheophyceae***
Codium edule	Limu wawale'iole	***Bryopsidophyceae***
Enteromorpha prolifera	Limu 'ele'ele/ green laver	***Ulvophyceae***
Ulva fasciata	Limu palahalaha	***Ulvophyceae***
Caulerpa lentillifera	Limu eka	***Charophyceae***
Monostroma nitidum	Aonori	***Ulvophyceae***

Algae in Nutraceuticals

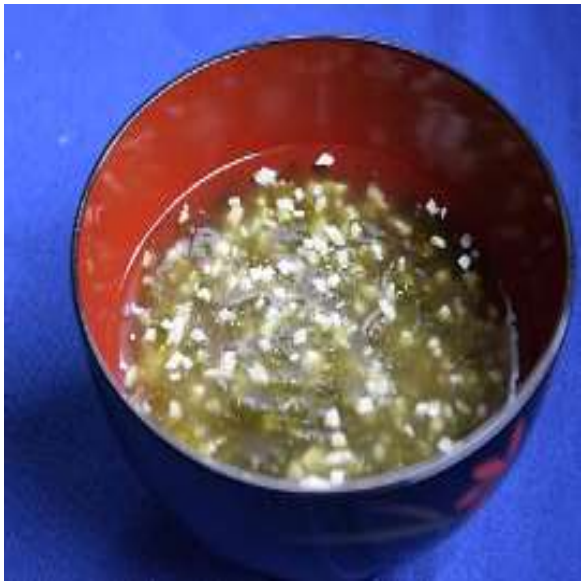
- ***Porphyra*** is excellent source of iodine, other trace minerals an dietary fibers, sugars are low (0.1%) and the vitamin content is very high with significant amounts of vitamin A, complex B and C
- It contains 3 major amino acids- alanine, glutamic acid and glycine
- It also contains taurine, which controls blood cholesterol levels

Gracilaria contains proteins, fiber, lipids, vitamin C, beta carotene and considered a very high value of vitamin activity for a food item, which makes it a potential source of beta carotene for human consumption

Alaria esculenta is said to have the best protein among the kelps and is also rich in trace metals and vitamins especially, niacin

Laminaria species has protein, fat, and useful amounts of minerals and vitamins, it has iron

Undaria has all essential amino acids, vitamins (especially Vitamin B complex), minerals and fiber contents along with iodine, beta carotene, and retinol etc.

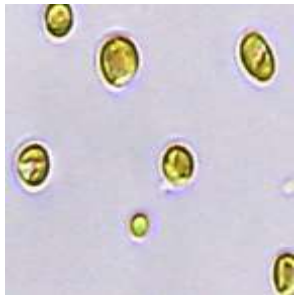


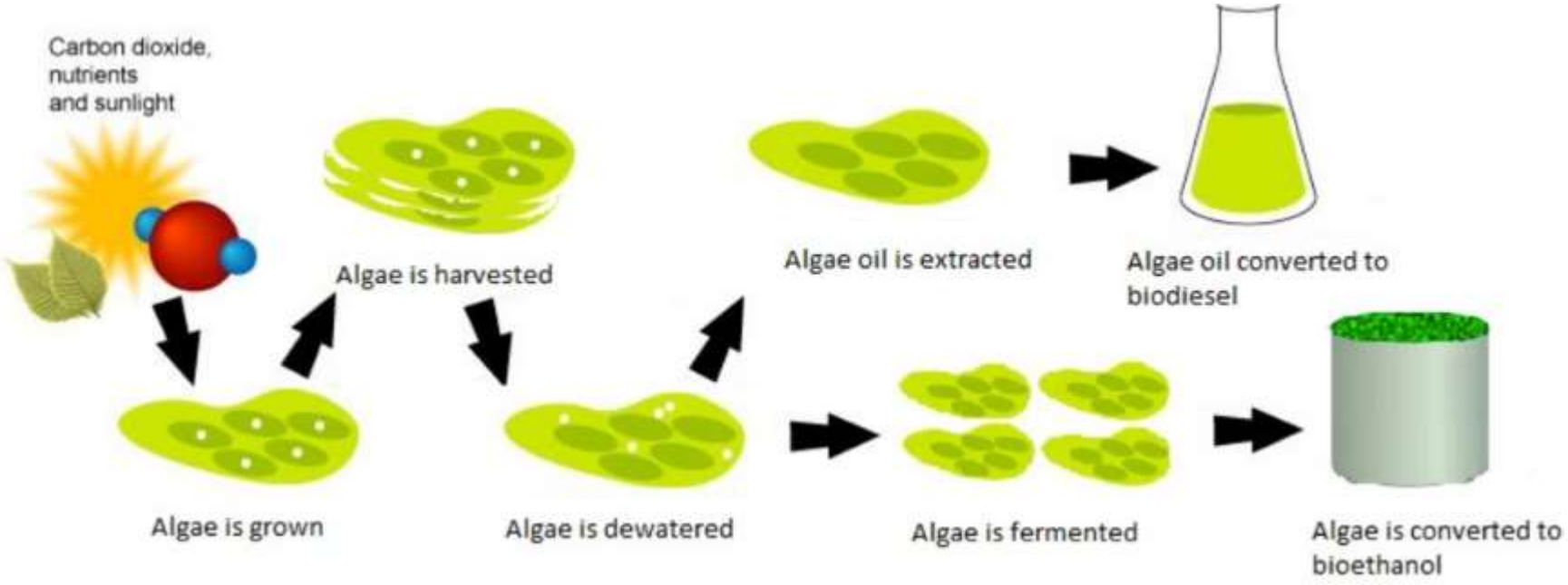
Monostroma latissimum has proteins, little fat, low sodium, high iron and calcium content, It has Vitamin B complex content in larger quantity than most vegetables. It is also rich in vitamin A

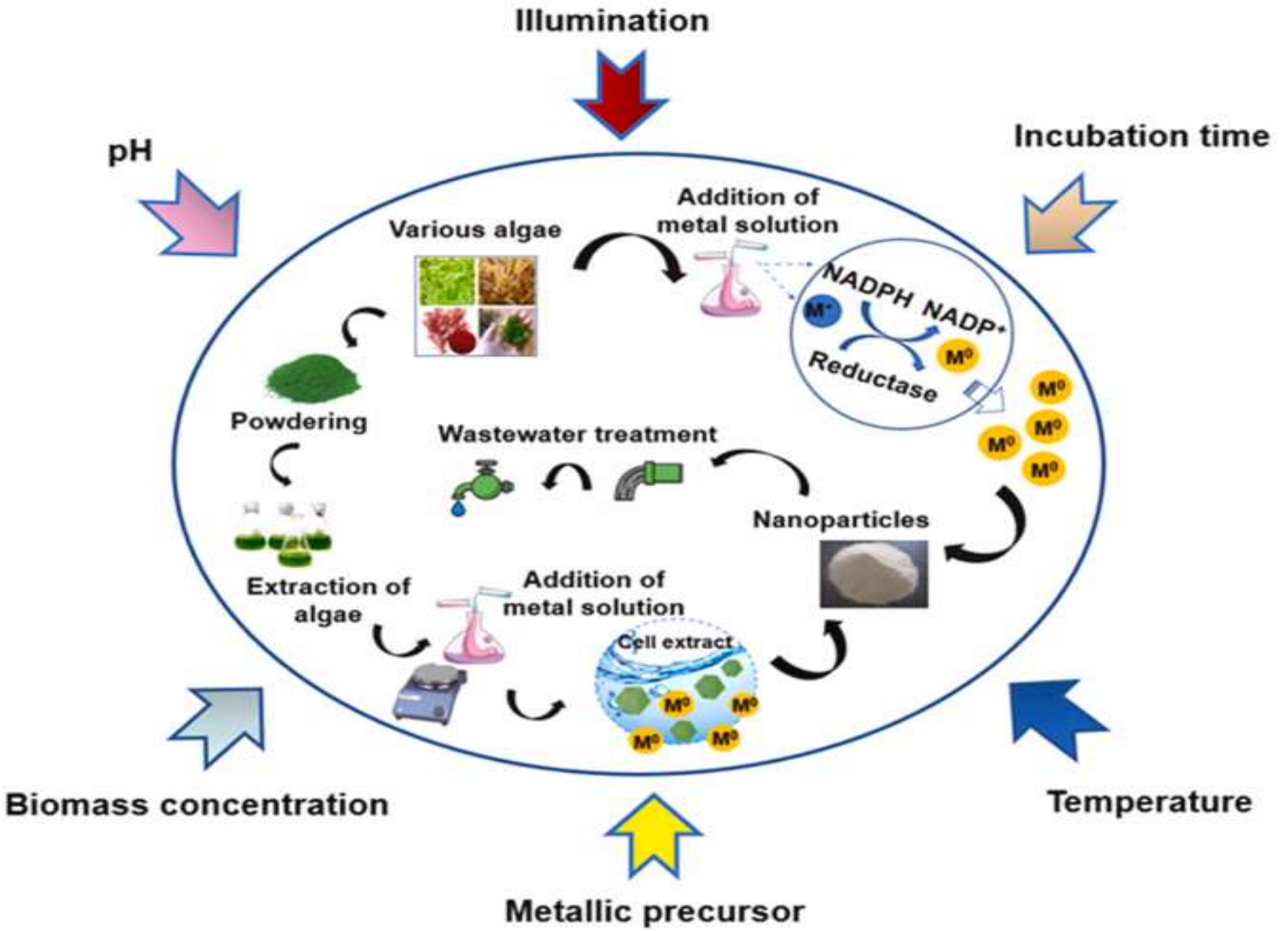
Ulva sp. Along with ***Monostroma*** and ***Enteromorpha*** are consumed as a part of 'aonori'. It has a higher protein content than the other two, but much lower vitamin content, except for niacin

Algae in Biotechnology

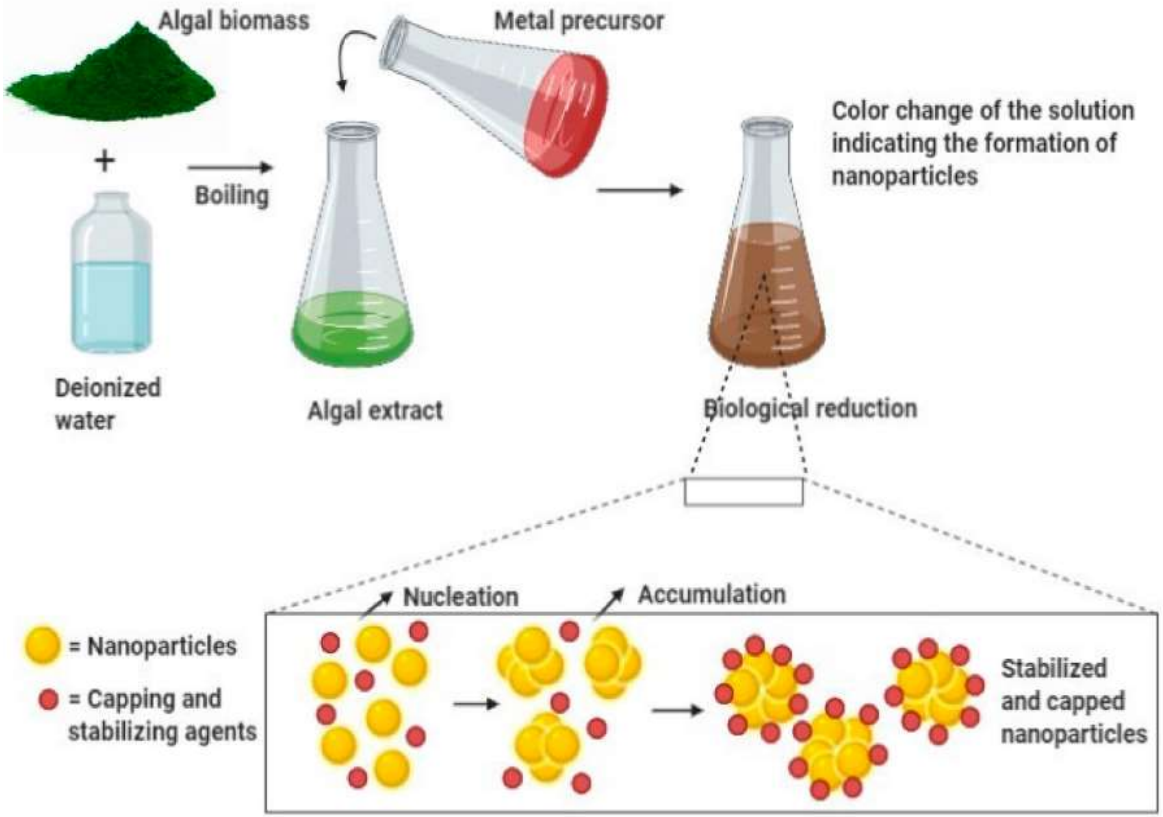
Several types of algae, including ***Chlorella***, ***Dunaliella***, ***Nannochloropsis***, and ***Isochrysis***, can be used to produce biofuels like biodiesel, bioethanol, and biohydrogen. These microalgae species are particularly promising due to their high oil content and fast growth rates, though economic viability remains a significant challenge.






Illumination
pH
Incubation time
Various algae
Addition of metal solution
NADPH NADP+
Reductase
Powdering
Wastewater treatment
Nanoparticles
Extraction of algae
Addition of metal solution
Cell extract
Biomass concentration
Temperature
Metallic precursor

Algae as Nanoparticle



It is proposed that using algae as a living cell factory or algal extract as a natural reducing agent is a green and clean way to efficiently synthesize various metallic nanomaterials. However, studies on algal-based biological synthesis of metallic nanomaterials and their applications towards removal of toxic pollutants from wastewater are still limited, which largely discourage the sustainability.

For example, in vivo bio-based synthesis of silver-based single crystals was performed using ***Pseudomonas stutzeri*** (Klaus-Joerger et al., 2001).

In vitro bio-based synthesis of gold nanoparticles using ***Sargassum wightii*** showed that gold nanoparticles can be synthesized within a short period via the biological reducing power (Singaravelu et al., 2007)

Some diatoms are capable of acting as the living cell factory to synthesize nanoparticles under proper cultivation conditions (Schröfel et al., 2011, Todd et al., 2014)

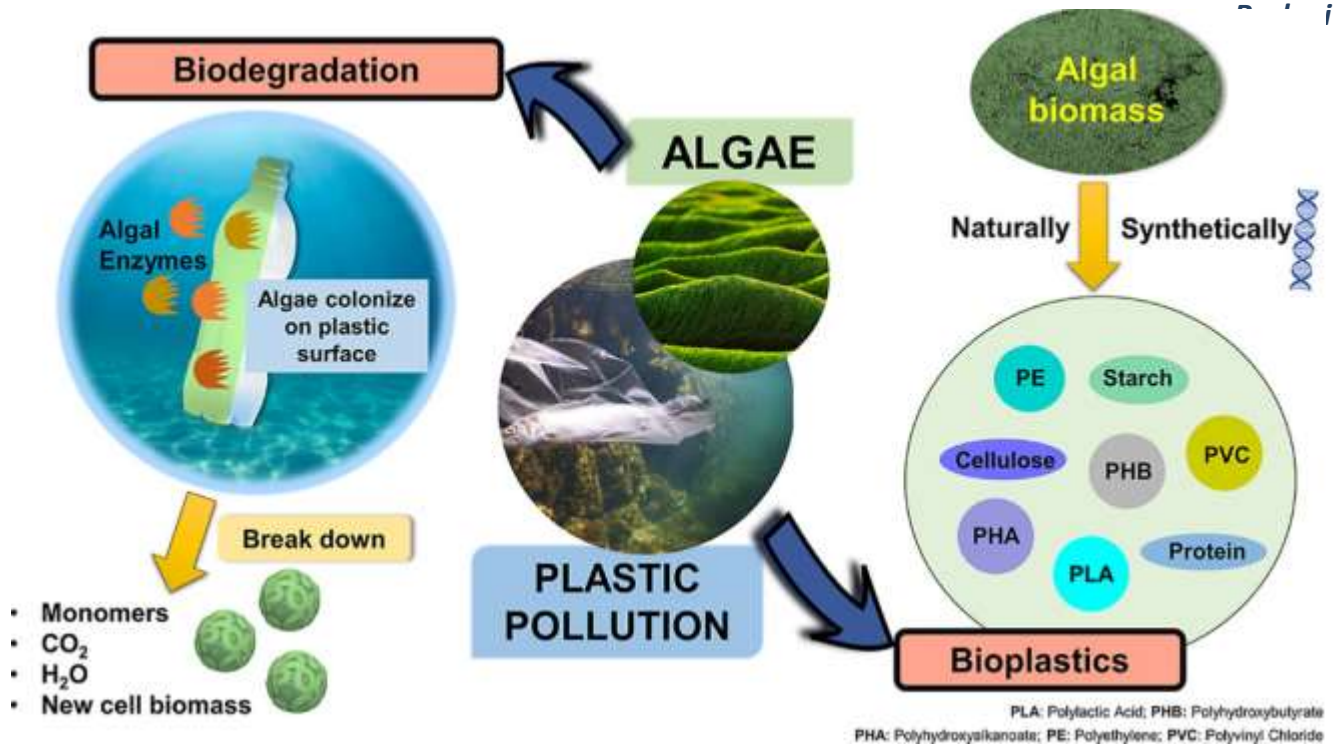
Seaweed and marine microalgae have shown enormous potential for use in many biotechnological fields due to their numerous bioactive components. Aquacultured marine macroalgae can be a sustainable source of biomass for the green production of metal oxide nanoparticles . Several studies have reported the use of different species of seaweed and microalgae for the green synthesis of Zinc oxide nanoparticles. Ex. ***Sargassum, Caulerpa, Gracilaria, Pterocladia, and Arthrospira*** are commonly used for the synthesis of Zinc oxide nanoparticles due to their high content of reducing agents and other bioactive compounds. Rhodophyta, in particular, has demonstrated potential for the green synthesis of Zinc oxide nanoparticles due to the presence of unique bioactive components that enhance the reduction of metal ions and prevent the growth of nanoparticles . Marine macroalgae have an advantage over terrestrial plants in the biosynthesis of Zinc oxide nanoparticles because they do not compete for agricultural land or freshwater resources. As a result, they are a sustainable source for large-scale production of green nanoparticle synthesis. (10)

Algae in nanoparticle extraction

Algae in Pigment extraction

Carotenoids are a class of widespread fat-soluble pigments that form a polyene chain that is sometimes terminated by rings. In addition to their role in coloration, some carotenoids (α-carotene, β-carotene and β cryptoxanthin) are provitamin A carotenoids, meaning they can be converted by the body to vitamin A (retinol). Moreover, carotenoids are biological antioxidants, protecting cells and tissues from the damaging effects of free radicals and singlet oxygen. Therefore, carotenoids are utilized in pharmaceuticals, health food, dietary supplements, cosmetics and as feed additives. The carotenoid, β-carotene and other carotenoids like canthaxanthin and lutein are produced in large scale amounts from the halophilic green microalga ***Dunaliella salina***. To a lesser extent, these carotenoids are isolated from ***Dunaliella bardawil, Haematococcus pluvialis, Chlorella vulgaris, Coelastrella striolata and Scenedesmus almeriensis***

Algae in Bioplastic



There are several initiatives on the development and production of algae-based bioplastic compounds. One of the objectives is to produce compostable plastics. Even if pure algae can be made into plastics, the products still lack the necessary performance specifications for the majority of applications. To solve this problem, the algae are currently blended with base resins like polyethylene, polypropylene and ethylene vinyl acetate. Both the type of algae biomass and the type of base resin influence the plastics characteristics. Algae biomass with a high protein content results in thermoplastics, while low protein contents result in a stronger and stiffer plastic. The bioplastic material can be used for injection molding, compression molding and thermoforming. An undesirable side effect of these bioplastics is their characteristic odor. Several components of marine algae possess therapeutic potential for calcium mineralization via osteoblastic differentiation. Therefore, some biomaterials from marine algae are used as biomimetic materials in bone therapy and bone tissue engineering

Algae in Economy and industry

- ***Arthrospira*** is harvested and consumed by the Kanembu who lived around Lake Kossorom
- The maximum yield in the period between June and September during rainy season
- Only Kanembu women carry out the harvesting; men are banned from entering the water, because it is a deep rooted belief that they would make the lake barren
- After harvesting it is dried on the mats in the sun
- It is traded in local markets, and in the markets of the main towns of Chad
- It is estimated that about 40 tons of dihe are harvested from this lake Kossorom every year, corresponding to a local trading value of more than US$100000 which represents an important contribution to economy of one of the poorest nations in the world

FIGURE 7.1 Harvesting of *Arthrospira* bloom from Lake Kossorom. (Courtesy of Dr. Gatugel Abdulqader.)

FIGURE 7.2 Drying of *Arthrospira* and preparation of *dihé* on the shore of Lake Kossorom. (Courtesy of Dr. Gatugel Abdulqader.)

- ***Porphyra*** has been cultivated in Japan and in the Republic of Korea since the 17th century
- Today ***Porphyra*** is one of the largest aquaculture industries in Japan, Korea and China. Because of its economic importance and other health benefits

- Dried Nori is in constant oversupply in Japan and producers and dealers are trying to encourage its use in the US and other countries
- Production and markets in China are expanding

- Whole dulse is packed for sale in plastic bags, 50g per bags and sold.
- In Canada, one company has cultivated it in land-based systems (tanks) and promotes it as a sea vegetable with the trade name “Sea Parsley”. It is a variant of normal dulse plants, but with small frilly outgrowths from the normally flat plant

- Fresh ***Gracilaria*** has been collected and sold as a salad vegetables in Hawaii (USA) for several decades

In Chile, the demand for edible macroalgae, ***Callophyllis variegata (carola)*** has increased. This red macroalgae has a promising future due to its high commercial value, which in 2001 was at about US$30KG/D.W.

Laminaria was originally native to Japan and the Republic of Korea, where it is cultivated since 1730. China developed a method for cultivating Laminaria which became a widespread source of income for large number of coastal families
China is now self sufficient in ***Laminaria*** and has a strong export market

Undaria sp. Along with ***Laminaria*** sp. Are one of the two most economically important edible algae. The cultivation accounts for about 50% of the about 8,00,000 wet tons of edible macroalgae produced annually in the Republic of Korea

Monostroma latissimum are green macroalgae cultivated in Japan and known as aonori or green laver
It can then either be processed into sheets and dried, for sale in shops, or dried, either outside or in dryers which has nutritional value

Algae as Medicine

Dihe is used as remedy applied onto wounds to speed up the healing process or as a poultice to soothe the pain and reduce the swelling of mumps

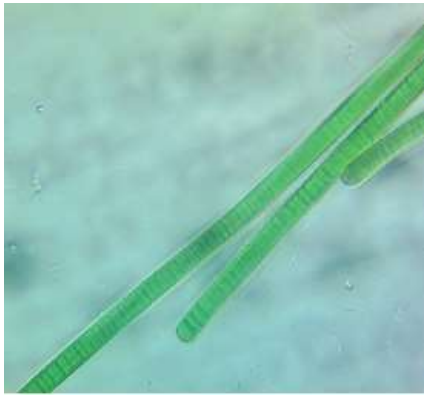
The alga is a preferred source of the red pigment r-phycoerythrin which is utilized as a fluorescent “tag” in the medical diagnostic industry

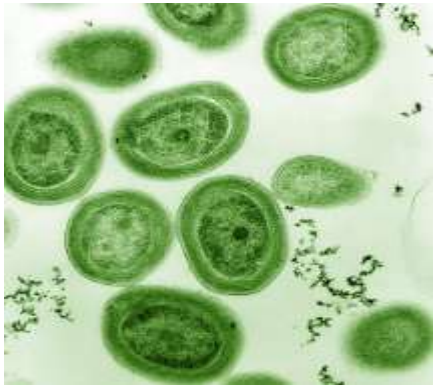
Porphyra (or sea algae) in shampoos can provide benefits like moisturizing and smoothing hair by fighting frizz, especially when combined with other hydrating botanicals like sea kelp. The specific benefits depend on the other ingredients in the formula, which can also include ingredients to strengthen hair, promote growth, or cleanse the scalp.

Gracilaria is sold as “sea moss” as it is reputed to have aphrodisiac properties and is also used as a base for a non-alcoholic drink

Cyanobacteria like ***Spirulina*** has been highlighted for its potential therapeutic applications in the area of immunomodulation, anticancer, antiviral and cholesterol reduction effects

Lyngbya lagerheimii and ***Phormidium tenue*** extracts are found to protect human lymphoblastoid T-cells from cytopathic effects of HIV infection

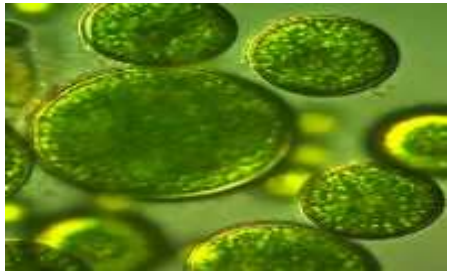




Studies of Water soluble extracts of cyanobacteria have found a novel sulfated polysaccharide, calcium spirulan to be a antiviral agent

Carraguard (Mixture of carrageenin similar to those extracted from Irish moss) has shown to be effective against HIV in vitro and against herpes simplex virus

A glycoprotein prepared from ***Chlorella vulgaris*** culture supernatant exhibited protective activity against tumor metastasis and chemotherapy-induced immunosuppression in mice



Fucoxanthin,a carotenoid commonly distributed in brown algae such as ***U. pinnatifida***, ***Laminaria religiosa*** is a potent drug and can be utilized as an excellent supplement like astaxanthin, because it acts as an antioxidant and inhibits cells of neuroblastoma and colon cancer cells

PUFA present in macroalgae are gaining increasing importance as valuable pharmaceutical products and ingredients of food owing to their beneficial effect on human health

Polysaccharides of microalgae and brown macroalgae selectively inhibits reverse transcriptase enzyme of human immunodeficiency virus (HIV)

Paramylon which belongs to group of naturally occurring polysaccharides are known to inhibit the growth of various tumors
Sulfated derivatives of ***Euglena*** Paramylon, have shown anti-HIV activity and cholesterol lowering effect when incorporated in the diet of humans and moderates the postprandial blood glucose and insulin response in humans

Algal extracts

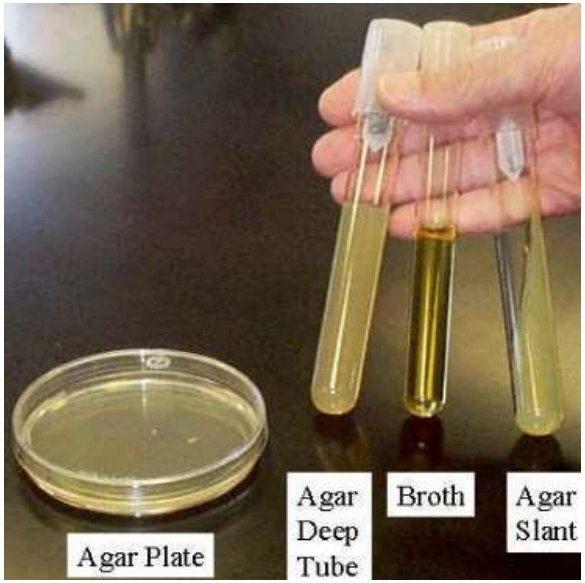
Extracts:

Agar, Alginates(derivatives of alginic acid) and carrageenin are 3 hydrocolloids that are extracted from various red and brown macroalgae

Agar, alginate and carrageenin are water soluble carbohydrates used to thicken aqueous solutions to form gels (jellies), gums and to stabilize certain products such as ice creams

Agar:

- It is used as a solid microbiological culture substrate
- The higher quality agar (bacteriological grade agar) is extracted from species of the red algal genera ***Pterocladia*** and ***Gelidium***
- Agar of lesser quality are extracted from ***Gracilaria*** and ***Hypnea*** species
- Food grade agar is seasonal in ***Pterocladis*** species



Alginate:

- These are the cell wall constituents of brown alga (Phaeophyceae)
- The alginates are extracted out from ***Macrocystic pyrifera, Ascophyllum nodosum, Laminaria hyperborea*** etc
- It is widely used in textile industry because they form excellent dressing and polishing material
- Calcium alginate is extruded to make fiber which is then woven into a gauze like product
- It is also used in the manufacture of a medical dressing very suitable for burns and extensive wounds
- Alginates are also used as thickening paste for colors in printing textiles, as a hardener and thickener for joining threads in weaving
- It is also used in glazing, sizing paper, special printer's inks, paints, cosmetics, insecticides and pharmaceutical preparations
- In US it is used as stabilizers in ice cream and also as a suspending agent in milk shakes

Carrageenin:

The general name for polysaccharides extracted from certain kinds of algae which are built up from D-galactopyranose units

The word carrageenin is derived from the colloquial Irish name for this macroalgae, ‘ carrageen’ (from the Irish place name)

Chondrus crispus is used to extract a gel

It is used in carrageenin industry to give a gel with particular qualities

Carrageenan
Seaweed derived gelling agent.
Directions:
CAUTION – Keep dyes, paints and chemicals away from children.
Net wt. 4 oz/113g

Algae as animal feed

Algae are utilized in aquaculture as live feeds for all growth stages of bivalve mollusks for the larval/ early juvenile stages of crustaceans and some fish species, and for zooplanktons used in aquaculture food chains

Successful strains for bivalve culture includes ***Isochyrsis galbana, Pavlova lutheri, Tetraselmis suecica, Pseudoisochrysis paradoxa, Chaetoceros calcitrans and Skeletonema costatum***

Animals like sheep, cattle and horses that lived in coastal areas have eaten macroalgae, especially in those European countries where large brown macroalgae were washed ashore ***Ascophyllum nodosum, Laminaria digitata*** are animals' favorite

In fish farming, wet feed usually consists of meat waste and fish waste mixed with dry additives containing extra nutrients along with binder (alginate extracted from algae) was used so that the doughy mass when thrown into the fish ponds must hold together and not disintegrate or dissolve in water

Algae in agriculture

Part of algal mass (***Sargassum***) is composted and then used for growing tomato plants in various types of soil

Macroalgae meal is dried, milled macroalgae, (***Ascophyllum***) are sold as soil additives and functions as both fertilizer and soil conditioner as they have suitable content of N, P and K, The large amounts of insoluble carbohydrates is brown macroalgae act as soil conditioners (improve aeration and soil structure, especially in clay soils) and have good moisture retention properties

Spraying the steep slopes with composted ***Ascophyllum***, clay, fertilizer, seed mulch and water has given good results, in cultivation of crops and even on bare rocks

Afrikelp (made from ***Ecklonia maxima***) is a commercially available dried macroalgae, sold as fertilizer and soil conditioner

Maerl bed

Maerl is common name of fertilizer derived from calcareous red algae; Maerl extracts are marketed mainly for use as an agricultural fertilizer, for soil improvement in horticulture, mainly to replace lime as an agricultural soil conditioner. Other uses are as animal food additive, for biological denitrification and in neutralization of acidic water in the production of drinking water, aquarium gravel as well as in pharmaceutical, cosmetics, nuclear and medical industries

Macroalgae extracts, composts when applied to fruit, vegetable and flower crops have shown some improvements like higher yields, increased uptake of soil nutrients, increased resistance to some pests like red spider mite and aphids, improved germination and more resistant to frost

Diatomaceous Earth Powder is a natural, soft sedimentary rock made from the fossilized remains of ***diatoms***, a type of hard-shelled algae. It is rich in silica, a vital trace mineral that plays a crucial role in various bodily functions.

It is widely used in organic gardening and agriculture as a natural insecticide and pest control agent. The fine powder particles have sharp edges that can cut through the exoskeletons of insects, causing them to dehydrate and die.

When added to soil, diatomaceous earth can enhance its structure, aeration, and drainage. It also helps in retaining moisture and nutrients, making it a valuable addition for both indoor and outdoor gardening.

Unlike many chemical pesticides, diatomaceous earth is non-toxic to humans, pets, and beneficial insects like bees and ladybugs. It's also considered an environment friendly option as it does not harm the ecosystem when used responsibly.

Diatomaceous Earth Powder is widely used in various industrial applications, including water filtration and as an absorbent material. Due to its porous structure, it has the ability to capture and remove impurities, making it a valuable component in filtration systems and spill cleanup processes.

Algae in cosmetics

Undaria Algae Body Oil and cream is a clinically proven, seaweed-infused body oil that instantly improves the look of skin elasticity and deeply moisturizes for a healthy, full-body

Alaria esculenta extract, this cream offers a potent blend of active ingredients that promote improved elasticity and a radiant complexion.

Powder made using ***Diatoms,*** It has a high absorption power and cation exchange capacity. When applied on pimples it absorbs all the sebaceous liquid from the pimple and makes it dry, thereby giving fast relief from pimples

Serum made of ***Phaeodactylum tricornutum*** has Anti-aging, antioxidant, anti-inflammatory, photoprotective, anti-melanogenic property

Sea algal serum made from Red, Brown and green algae Fade dark spots, acne scars, and get even skin tone. Control oil, minimize pores, and improve overall skin health.

Rashmi M G

Milled macroalgae, packed in sachets are sold as an additive to bath water, bath salts with macroalgae meal are also sold

Thallassotherapy, where macroalgae pastes, made by cold grinding or freeze crushing are applied to a person's body and then warmed under infrared radiation is said to provide relief from rheumatism and osteoporosis

Mineral rich sea water is used in a range of therapies like, hydrotherapy, massage and variety of marine mud and algae treatments

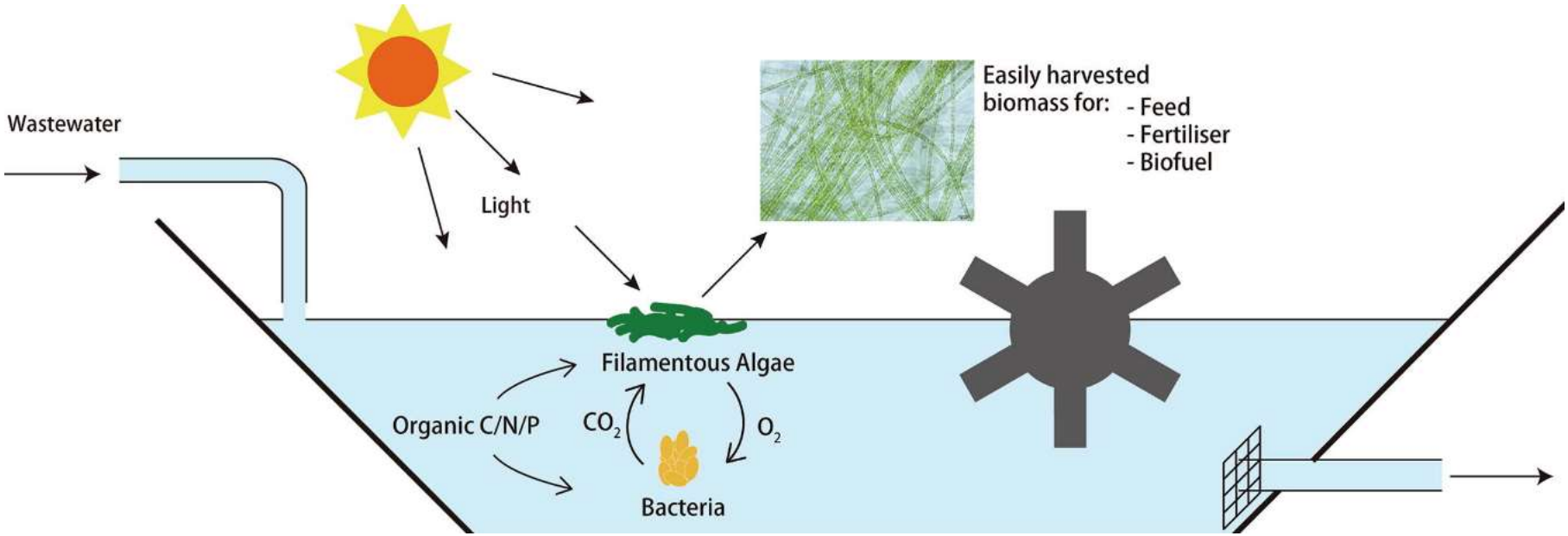
Paste mixtures are used in massage creams with promises to rapidly restore elasticity and suppleness to the skin

Macroalgae are used in creams, facemasks, shampoos, body gels, bath salts and even a DIY body wrap kit

Importance of Algae in Environment

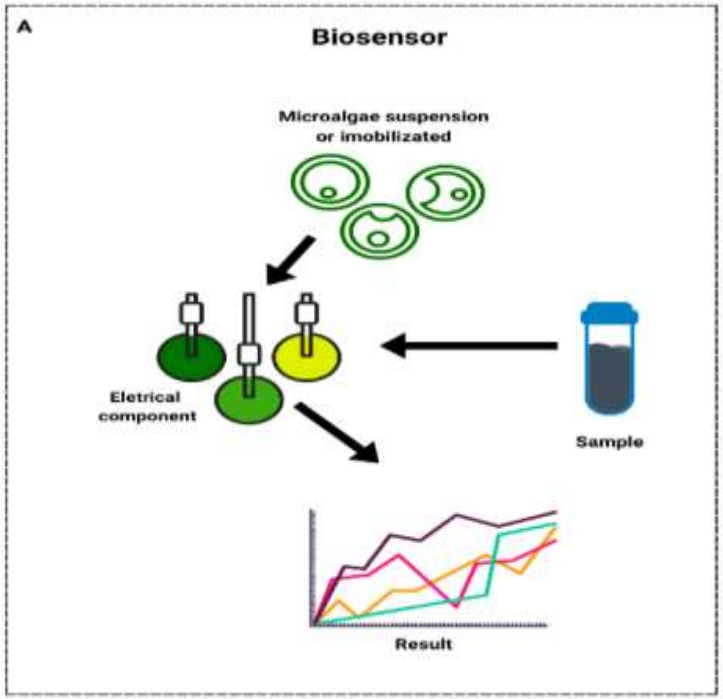
Algae in waste water treatment

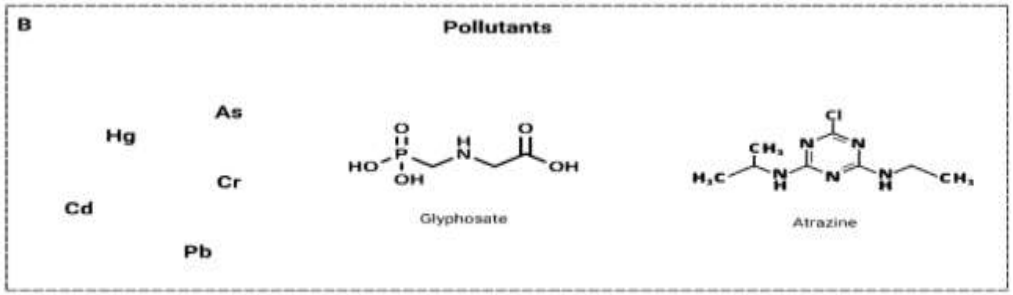
Algae that are applicable to wastewater treatment must tolerate a wide variation in medium conditions. The most tolerant eight microalgal genera were found to be ***Euglena, Oscillatoria, Chlamydomonas, Scenedesmus, Chlorella, Nitzschia, Navicula and Stigeoclonium***. Overall, more than 1000 algal taxa have been reported one or more times as pollution tolerant, which include 240 genera, 725 species and 125 varieties and forms; the most tolerant genera include eight green algae, five blue-greens, six flagellates and six diatoms. Even the green macroalgae ***Ulva*** spp. and ***Monostroma*** spp. were shown to be suitable for reduction of nitrogen- and phosphorus compounds in wastewater.



Algae in Biosensors

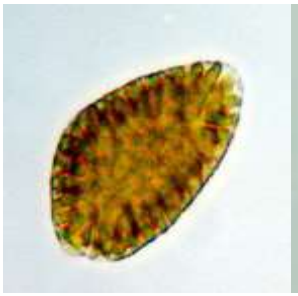
Unicellular green alga ***Dunaliella tertiolecta*** and the diatom ***Phaeodactylum tricornutum*** have been successfully used as biosensors to analyze most widely represented herbicides, i.e., atrazine, diuron and glyphosate, as well as several of their photodegradation products (DCPU, DCPMU, AMPA) . Biosensors frequently use a suspension of algal cells as a bioreceptor and operation of the transducer and detection system is based on measuring either chlorophyll fluorescence or extracellular enzyme activity (e.g., membrane esterase) using optical or conductometric measuring devices. Instead of using a suspension of algal cells, microalgae can also be immobilized in alginate and silica hydrogels for use as a bioreceptor. The microalgae ***Chlorella vulgaris, Pseudokirchneriella subcapitata and Chlamydomonas reinhardtii*** were suitable species for this kind of immobilization

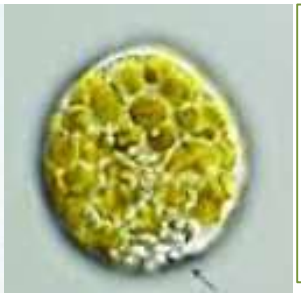




Algal toxins

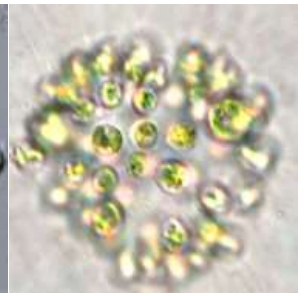
Toxins of algae can attract particular attention when they cause the death of livestock that has drunk water containing them or fish and shellfish in the sea or humans that consume these
Toxins have been divided into different classes based on the syndromes associated with exposure to them, such as, Paralytic shellfish poisoning (PSP), diarrheic shellfish poisoning (DSP), neurotoxic shellfish poisoning (NSP), ciguatera fish poisoning (CFP) and amnesic shellfish poisoning (ASP)

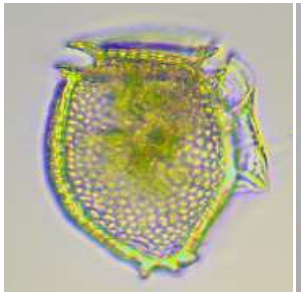




Chattonella and ***Heterosygma*** species which belong to Raphidophyceae, form red tides in Japanese waters and a few diatoms of the genus ***Peusdonitzschia*** produce domoic acid, a low molecular amino acid causing ASP

Cyclic peptides like Nodularins of ***Nodularia***, microcystins of ***Microcystis*** causes risk to recreational swimmers Symptoms like weakness, loss of appetite, vomiting and diarrhea to cancer are associated





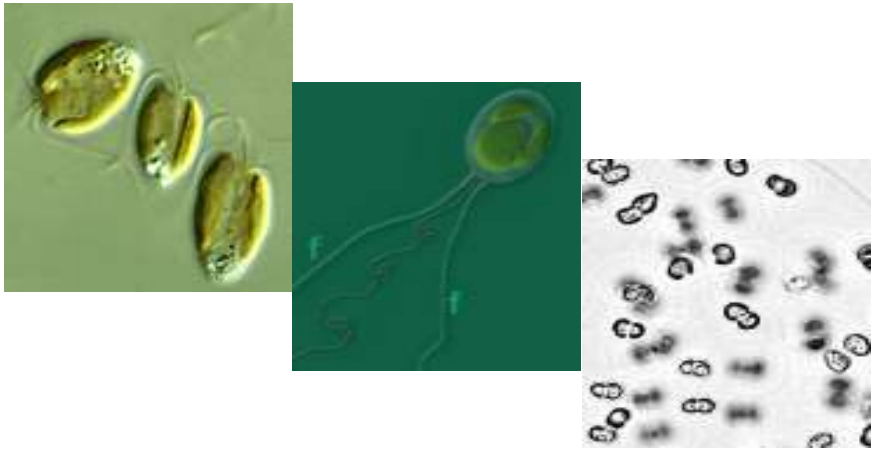
Toxins of ***Dinophysis*** and ***Prorocentrum lima*** causes mild GI disorder, nausea, vomiting, diarrhoea, abdominal pain accompanied by chills, headache and fever.

Alkaloids like Anatoxin of ***Anabaena*** affect the nervous system, skin, liver, GI tract. These neurotoxins can cause symptoms of diarrhea, shortness of breath, convulsions and death. In high doses, due to respiratory failure, these toxins causes PSP in humans consuming contaminated shellfish. Saxitoxin of ***Alexandrium*** spp. Affects neurologically which includes tingling, burning, numbness, drowsiness, incoherent speech, respiratory paralysis

Prymnesium parvum produces a potent toxin that causes extensive fish mortality in brackish water

Chrysochromulina polylepis produces and excretes glycolipids with hemolytic and ichtytoxic properties causing osmoregulatory failure

Phaeocystis sp. Is familiar to fishermen in the form of extensive blooms of mucilaginous colonies, which are avoided by herring, It produces large quantities of acrylic acid, which has strong bactericidal properties



Toxins of ***Gymnodinium breve*** causes NSP which is associated with symptoms like tingling, numbness of lips, tongue, throat, muscular aches, dizziness, reversal of the sensations of hot and cold etc

Scientific Name	Class	Toxin
Nodularia spp.	***Cyanophyceae***	Nodularin
Microcystis spp.	***Cyanophyceae***	Microcystin
Chondrus armata	***Floridophyceae***	ASP domoic acid
Prymnesium parvum	***Haptophyceae***	Fish toxin
Phaeocystis pouchetii	***Haptophyceae***	PUA
Chrysochromulina polylepis	***Haptophyceae***	Ichtytoxic glycolipids
Alexandrium spp.	***Dinophyceae***	PSP
Dinophysis spp.	***Dinophyceae***	DSP
Prorocentrum lima	***Dinophyceae***	DSP
Gymnodinium breve	***Dinophyceae***	NSP
Ptychodiscus brevis	***Dinophyceae***	NSP
Gambierdiscus toxicus	***Dinophyceae***	Ciguatoxin/maitotoxin
Pseudonizschia spp.	***Bacillariophyceae***	ASP domoic acid
Thalassiosira rotula	***Bacillariophyceae***	PUA
Skeletonema costatum	***Bacillariophyceae***	PUA

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